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### (54) Optical subassembly for use in fiber optic data transmission and reception

(57) An optical subassembly (10; 40) and a method of fabricating the same utilize a subassembly body (14; 44) that is formed by molding the subassembly body onto a substrate (16; 46). Preferably, the subassembly body is constructed of a plastic material that can be molded into a precise shape. The subassembly body and the substrate become an integral unit when the molded plastic material is polymerized. The optical subassembly includes the subassembly body, the substrate, an optical element (12; 42), an optoelectronic device (18; 48), and a transceiver integrated circuit (IC)

chip (20; 50). The optoelectronic device and the transceiver IC chip are affixed to the substrate. Preferably, the substrate is a flexible circuit having a number of electrical traces. The flexible circuit may be composed of a polymer material. The optoelectronic device is positioned on the substrate such that the optoelectronic device is located within an opening (28; 53) in the subassembly body. The opening may become an enclosed cavity when the optical element is attached to the subassembly body.

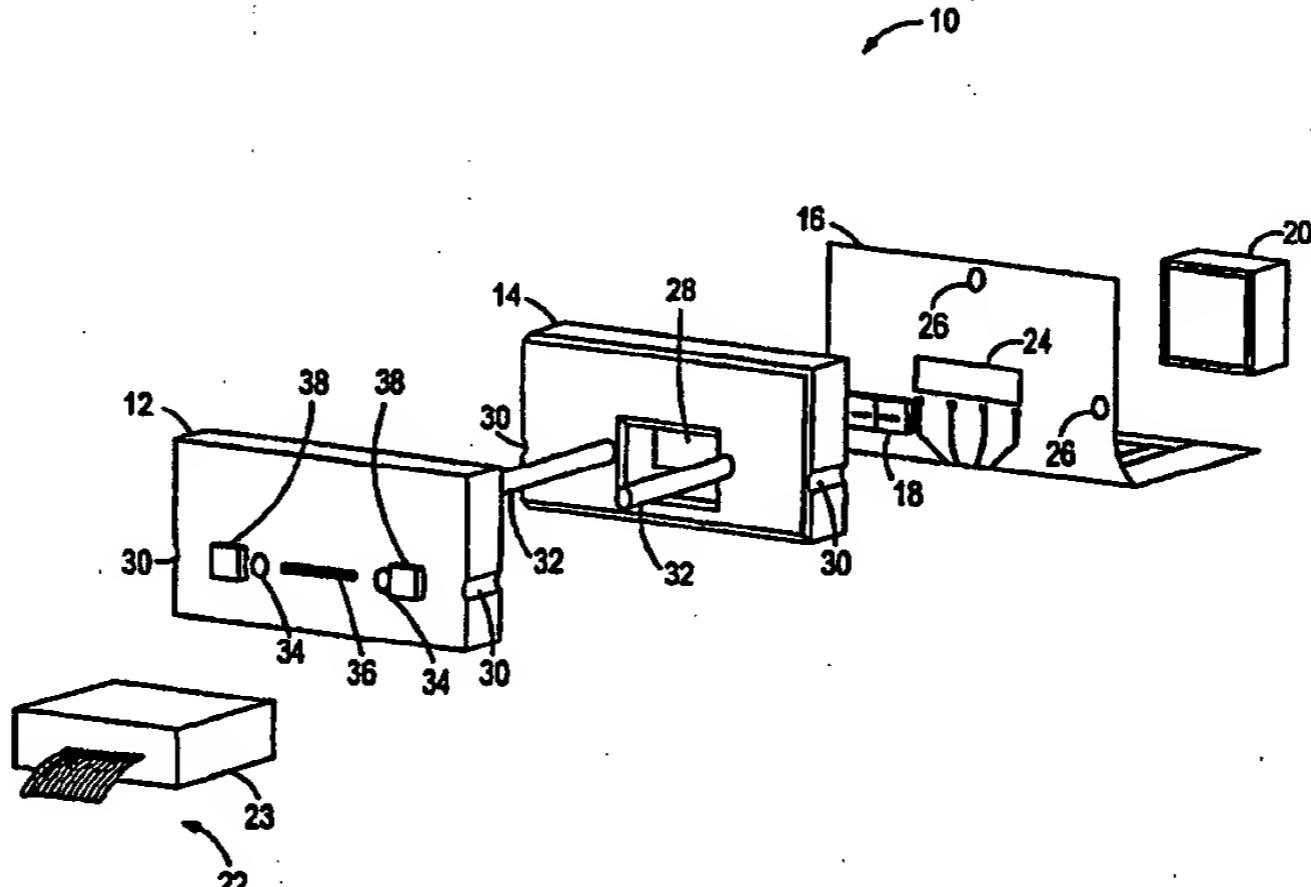


FIG. 1

**Description****TECHNICAL FIELD**

[0001] The invention relates generally to fiber optic devices and more particularly to an optical subassembly for use in fiber optical systems.

**DESCRIPTION OF THE RELATED ART**

[0002] When manufacturing a fiber optic device for interconnecting optical fibers, it may be beneficial to fabricate a portion of the device as an optical subassembly, which can be tested as a separate unit. For example, the optical subassembly may include a semiconductor light source or photodetector, and other optical components. If the optical subassembly is a transmission type, a semiconductor light source will typically be included in the optical subassembly. On the other hand, if the optical subassembly is a reception type, the optical subassembly will include a photodetector.

[0003] One major type of optical subassembly utilizes a transistor outline (TO) can package containing a semiconductor light source or a photodetector. An optical subassembly utilizing a TO can package is described in U.S. Pat. No. 5,537,504 to Cina et al. The optical subassembly of Cina et al. includes a molded plastic housing having a TO can package attached to one end of the housing. Epoxy type adhesive is used to attach the housing to the TO can package. The optical subassembly of Cina et al. also includes a lens that is placed within the molded plastic housing between the TO can package and an optical fiber.

[0004] A concern with optical subassemblies utilizing a TO can package is that TO can packages are relatively expensive. In addition, TO can packages do not typically accommodate a high density of electrical inputs and outputs, and are not compatible with most commercially available high-speed semiconductor assembly equipment. Furthermore, TO cans are bulky and result in electrical parasitics (e.g. capacitance, resistance, inductance) that limit the high-speed performance of such packages.

[0005] Another major type of optical subassembly utilizes a submount, e.g., a micro-machined silicon micro-bench, to support an optoelectronic device and other optical components. The submount is typically a semiconductor substrate having a number of etched depressions for affixing the device and components onto the submount. U.S. Pat. No. 5,264,392 to Gaebe et al. describes an optical subassembly having a silicon-based submount. The submount supports a cylindrically-shaped graded-index (GRIN) lens, an optical isolator, an optoelectronic device, and a spherical lens.

[0006] A concern with optical subassemblies utilizing a submount is that, similar to the TO can type optical subassemblies, submounts are generally expensive. In addition, quality material for fabrication of the sub-

mounts is presently available from only a limited number of vendors.

[0007] While known optical subassemblies operate well for their intended purposes, improvements in performance and reduction in fabrication cost are desired. In particular, low cost package designs which permit the assembly of multiple optical sources or detectors in a small volume are needed.

**10 SUMMARY OF THE INVENTION**

[0008] An optical subassembly and a method of fabricating the same utilize a subassembly body that is formed by molding the subassembly body onto a substrate. Preferably, the subassembly body is formed of a polymeric material that can be molded into a precise shape directly onto the substrate. The subassembly body and the substrate become an integral unit when the molded polymeric material is polymerized.

[0009] In a first embodiment of the invention, the optical subassembly facilitates transmission or reception of light signals that are propagating exclusively in a single plane. The optical subassembly of the first embodiment includes an optical element, the subassembly body, the substrate, an optoelectronic device, and a transmitter or receiver integrated circuit (IC) chip. As stated above, the subassembly body and the substrate form an integral unit. The other components are attached to the integral unit. The optoelectronic device and the transmitter/receiver IC chip may be affixed to the substrate, while the optical element is affixed to the molded subassembly body. Preferably, the substrate is a flexible circuit having a number of electrical traces. The flexible circuit may be composed of a polymer material. The optoelectronic device may be a light source and/or detector that is affixed to one side of the flexible circuit, while the transmitter/receiver IC chip is affixed to the opposite side. Alternatively, the transmitter/receiver IC chip may be affixed to the same side of the flexible circuit with respect to the light source and/or detector. The position of the transmitter/receiver IC chip on the flexible circuit is not critical to the invention. The optoelectronic device is positioned on the substrate such that the optoelectronic device is located within an opening in the subassembly body.

[0010] The optoelectronic device and the transmitter/receiver IC chip may be affixed to the substrate using a conductive epoxy, solder, or other comparable material. In addition, the optoelectronic device and the transmitter/receiver IC chip may be electrically connected to the substrate by wire connections or via flip chip contacts. Additional optoelectronic devices and their associated transmitter/receiver IC chips may be affixed to the substrate.

[0011] The optical element is preferably attached to the subassembly body. The rearward face of the optical element is positioned such that the opening of the subassembly body containing the optoelectronic device

becomes an enclosed cavity that encapsulates the optoelectronic device. The optical element may be one or more lenses or other optics designed to provide an efficient coupling of optical fibers to the optoelectronic device. The optical element may incorporate mechanical stand-offs to ensure that proper spacing is maintained between the optical fibers and the optical element when a fiber optic ribbon cable is attached to the optical subassembly.

[0012] A second embodiment of the invention includes the same components of the optical subassembly as the first embodiment of the invention, but with a different configuration of the optical element, the subassembly body, and the substrate. The configuration of the optical subassembly in accordance with the second embodiment is primarily designed to accommodate light signals that are emitted or received in a first direction by the optoelectronic device. However, the light signals are transmitted to or received from optical fibers in a direction that is perpendicular to the first direction. This is rendered possible by an optical element which provides a 90 degree optical turn for light signals in order to redirect horizontally propagating light signals from the optical fibers into a vertical direction, or direct vertically propagating light signals from the optoelectronic device into a horizontal direction. The optical element may include optical guiding veins or channels to change the propagating direction of light signals.

[0013] To facilitate the change in the propagating direction of light signals, the subassembly body is configured such that the optical element is attached to the forward face of the subassembly body, while the substrate is located at the bottom of the subassembly body. The optoelectronic device is affixed to the substrate to receive or emit light signals in a vertical direction. In the second embodiment, the optoelectronic device and the transmitter/receiver IC chip are affixed to the same side of the substrate. However, the location of the transmitter/receiver IC chip on the substrate is not critical to the invention. Similar to the first embodiment, additional optoelectronic devices and their associated transmitter/receiver IC chips may be affixed to the substrate to couple more optical fibers.

[0014] A method of fabricating an optical subassembly in accordance with the invention initially involves a step in which a substrate having electrical traces is provided. The substrate can be provided in a panel form to fabricate a number of the optical subassemblies in a parallel fabrication manner. Preferably, the substrate is a flexible circuit containing sufficient circuitry to accommodate a number of optoelectronic devices and their associated transmitter/receiver IC chips. Next, a subassembly body is formed on the substrate by a molding process. The molding process may involve transfer molding or injection molding thermoplastic resin onto the substrate. Preferably, the substrate includes holes through which the plastic material flows during this step, allowing the subassembly body to become integrally bonded to both

sides of the substrate, such that the subassembly body and the substrate become an integrated unit.

[0015] The subassembly body may be formed to include mechanical features and indentations. The mechanical features can be used to align an optoelectronic device and an optical element with respect to the subassembly body. The indentations allow the optical subassembly, when fully assembled, to be attached to a housing of a comprehensive fiber optic device.

[0016] After the subassembly body is molded onto the substrate, an optoelectronic device and a transmitter/receiver IC chip are physically affixed and electrically connected to the substrate. The optoelectronic device and the transmitter/receiver IC chip may be affixed to the substrate using a conductive epoxy or solder materials. This electrical connection step may involve wire connections or flip chip contacts. Next, an optical element can be attached to the subassembly body.

[0017] An advantage of the present invention is the low cost of manufacturing the optical subassembly in accordance with the present invention by utilizing an inexpensive molding process to form the subassembly body. In addition, the use of the molding process provides a subassembly body having high precision dimensions that may be utilized to align an optical element to the optoelectronic device.

[0018] Another advantage is that the substrate permits optoelectronic devices and their associated transmitter/receiver IC chips to be placed in close proximity. The close proximity reduces the length of electrical traces connecting the optoelectronic devices and the transmitter/receiver IC chips. The decrease in the length of electrical traces translates to increasing the bandwidth of a device utilizing the optical subassembly in accordance with the invention.

[0019] Still another advantage of the present invention is that mechanical strain relief is provided for electrical contacts, e.g., solder or conductive epoxy contacts, between the optical subassembly and a secondary circuit board. The use of flexible circuit as the substrate virtually eliminates stresses that are typically transferred to the electrical contacts by insertion or extraction of a connectorized fiber optic ribbon cable.

[0020] Still another advantage relates to the ease of fabricating the optical subassemblies using the panel form. By fabricating the optical subassemblies in the panel form, manufacturing cost can be lowered. In addition, standard high-speed semiconductor assembly equipment can be utilized in the fabrication process.

[0021] Still another advantage is that assembling the optical element to the subassembly body can provide a sealed cavity that encapsulates the optoelectronic devices without adding a costly step of over-molding or glob topping to the manufacturing process. The sealed cavity provides environmental protection for the optoelectronic devices during the life of the product.

optoelectronic device 48 and the transmitter/receiver IC chip 50 may be positioned in close proximity when attached to the flexible circuit 46. The physical attachment and electrical connection of the optoelectronic device 48 and the transmitter/receiver IC chip 50 to the flexible circuit 46 can be accomplished in the same manner as described above in reference to affixing the optoelectronic device 18 and the transmitter/receiver IC chip 20 to the flexible circuit 16.

[0035] Similar to the subassembly body 14 of the optical subassembly 10, the subassembly body 44 includes two rods 58 for attaching the optical element 42 onto the subassembly body 44. However, unlike the subassembly body 14, the subassembly body 44 has recesses on the forward face 60 of the subassembly body 14. The recesses allow the optical element 42 to fit into the subassembly body 44. The recesses may be configured to allow the forward face 62 of the optical element 42 to be flush against the forward face 60 of the subassembly body 44, when the optical element 42 is fitted into the subassembly body 44. Although not shown in Fig. 2, the optical element 42 may contain an array of lenses similar to the optical element 12 of the subassembly body 10. In addition, the optical element 42 may include mechanical stand-offs on the forward face 62 to provide proper spacing when optical fibers are placed against the optical element 42.

[0036] The optical element 42 includes two bores 64, similar to the bores 34 of the optical element 12. The bores 64 of the optical element 42 allow the rods 58 to be inserted into the optical element 42 to attach the optical element 42 to the subassembly body 44. The optical element 42 also includes an L-shaped section 66. If the optical subassembly 40 is a reception type optical subassembly, the L-shaped section 66 directs horizontally propagating light signals from optical fibers to travel in a vertical direction to the optoelectronic device 48. However, if the optical subassembly 40 is a transmission type optical subassembly, the L-shaped section 66 directs vertically propagating light signals from the optoelectronic device 48 to travel in a horizontal direction to the optical fibers. The L-shaped section 66 may contain optical guiding veins or channels to direct propagating light signals to or from the optical fibers.

[0037] In operation, an array of optical fibers is placed against the optical element 42. The fiber array may be contained in a fiber holder, similar to the fiber holder 23. The fiber holder may contain two bores, such that the rods 58 of the subassembly body 44 may be inserted into the bores of the fiber holder to align the fiber array to the optoelectronic device 48. In a reception type configuration, light signals are transmitted from the fiber array. The light signals initially impinge upon the forward face 62 of the optical element, propagating in a horizontal direction. The horizontally propagating light signals are then directed by the L-shaped section 66 of the optical element 42 to propagate in a vertical direction, down toward the optoelectronic device 48. The light signals

are received by the optoelectronic device 48, which would be a photoreceptor. In a transmission type configuration, light signals are emitted from the optoelectronic device 48. In this configuration, the optoelectronic device 48 is a semiconductor light source, such as a laser or a LED. The light signals initially propagate in a vertical direction to the L-shaped section 66 of the optical element 42. However, the L-shaped section 66 directs the light signals to travel in a horizontal direction. The light signals are then transmitted to the optical fibers in the fiber array.

[0038] A method of fabricating an optical subassembly in accordance with the invention will now be described with reference to Fig. 3. At step 110, a substrate having electrical traces is provided. Preferably, the substrate is a flexible circuit containing sufficient circuitry to accommodate a number of optoelectronic devices and their associated transmitter/receiver IC chips. The substrate is preferably provided in a panel form, with multiple units arranged in rows and in close proximity to each other. At step 120, a subassembly body is formed on the substrate by a molding process. The molding process may involve transfer molding thermoset resin or injection molding thermoplastic resin onto the substrate. Preferably, the substrate includes holes for the plastic material to flow through during this step, allowing the subassembly body to become integrally bonded to both sides of the substrate such that the subassembly body and the substrate become an integrated unit.

[0039] The subassembly body may be formed to include mechanical features and indentations. The mechanical features can be used to align an optoelectronic device and an optical element with respect to the subassembly body. The indentations allow the optical subassembly, when fully assembled, to be attached to a housing of a comprehensive fiber optic device.

[0040] After the subassembly body is molded onto the substrate, an optoelectronic device is affixed to the substrate at step 130. The optoelectronic device may be affixed to the substrate using a conductive epoxy or solder materials. The precise location of the optoelectronic device can be determined by aligning the optoelectronic device with respect to alignment features on the subassembly body using conventional alignment methods, such as vision system or mechanical fixturing. Alternatively, the self-alignment capability inherent in the flip chip integrated chip attachment process may be utilized. At step 140, the optoelectronic device is electrically connected to the substrate. For example, optoelectronic device may be connected by wire connections or via flip chip contacts. Next, at step 150, the transmitter/receiver IC chip is affixed to the substrate. Similar to the step 140, the transmitter/receiver IC chip is electrically connected to the substrate at step 160. At this point, the optoelectronic device and the transmitter/receiver IC chip can be electrically tested, and "burned in" to identify units with potential reliability problems. Defective units may be physically marked and

excluded from further processing. Alternatively, the test and "burn in" procedure can occur later in the process.

[0041] After affixing the optoelectronic device and the transmitter/receiver receiver IC chip, an optical element can be attached to the subassembly body at step 170. Preferably, the optical element is automatically aligned with respect to the optoelectronic device by the physical attachment of the optical element to the subassembly body. However, the optical element may be aligned with the optoelectronic device by using a vision system incorporating pattern recognition. Alternatively, the optical element may be aligned with the optoelectronic device by using an active alignment process. In this process, power is applied to the optoelectronic device and the position of the optical element is determined by measuring and maximizing optical throughput in the optical subassembly.

### Claims

1. A method of fabricating an optical subassembly (10; 40) comprising steps of:

providing (110) a substrate (16; 46) having a plurality of conductive traces; said conductive traces configured to electronically interconnect at least one optoelectronic device (18; 48) and a supporting circuitry chip (20; 50); forming (120) a subassembly body (14; 44) directly onto said substrate by a molding process to mold a polymeric material into a preselected shape that defines said subassembly body, said polymeric material being molded into said preselected shape to provide a structural integrity of said optical subassembly and to establish a conduit for transmitting light signals to and from a plurality of optical lines (22).

2. The method of claim 1 wherein said step of forming (120) said subassembly body (14; 44) includes a step of integrally linking said subassembly body to said substrate (16; 46) such that said subassembly body and said substrate become an integrated unit.

3. The method of claim 1 or 2 wherein said step of forming (120) said subassembly body (14; 44) includes a step of conforming said polymeric material to include mechanical features (28; 53) on said subassembly body that can be utilized for optically aligning said at least one optoelectronic device (18; 48).

4. The method of claim 1, 2 or 3 further comprising a step of affixing (150) and electrically connecting (160) said supporting circuitry chip (20; 50) onto said substrate (16; 46).

5. The method of claim 1, 2, 3 or 4 further comprising

a step of affixing (130) and electrically connecting (140) said at least one optoelectronic device (18; 48) onto said substrate (16; 46) such that said at least one optoelectronic device is housed within said subassembly body (14; 44), said conduit providing an optical path for said light signals propagating between said optical lines (22) and said at least one optoelectronic device.

6. An optical subassembly (10; 40) for transmission or reception of light signals comprising:

a subassembly body (14; 44) structurally configured to provide a conduit through said subassembly body for transmitting a light beam to or from an optical line (22), said subassembly body providing structural integrity for said optical subassembly; a dielectric substrate (16; 46) having a configuration of conductive traces, said subassembly body being structurally integrated with said substrate; and an optoelectronic device (18; 48) electrically coupled to said conductive traces of said substrate for emitting or receiving said light beam to or from said optical line, said optoelectronic device being positioned to emit or receive said light beam through said conduit of said subassembly body.

7. The subassembly of claim 6 further comprising an integrated circuit chip (20; 50) electrically attached to said conductive traces of said substrate (16; 46), said integrated circuit chip being configured to provide supporting signal processing circuitry for said optoelectronic device (18; 48).

8. The subassembly of claim 6 or 7 wherein said dielectric substrate (16; 46) is constructed of a flexible material.

9. The subassembly of claim 6, 7 or 8 further comprising an optical lens (36) attached to said subassembly body (14; 44) such that said optical lens extends across said conduit of said subassembly body to form an enclosed cavity within said subassembly body, said enclosed cavity containing said optoelectronic device (18; 48).

10. The subassembly of claim 9 wherein said subassembly body (14; 44) includes physical features (32 and 34) that provide an alignment reference for said optical lens (36).

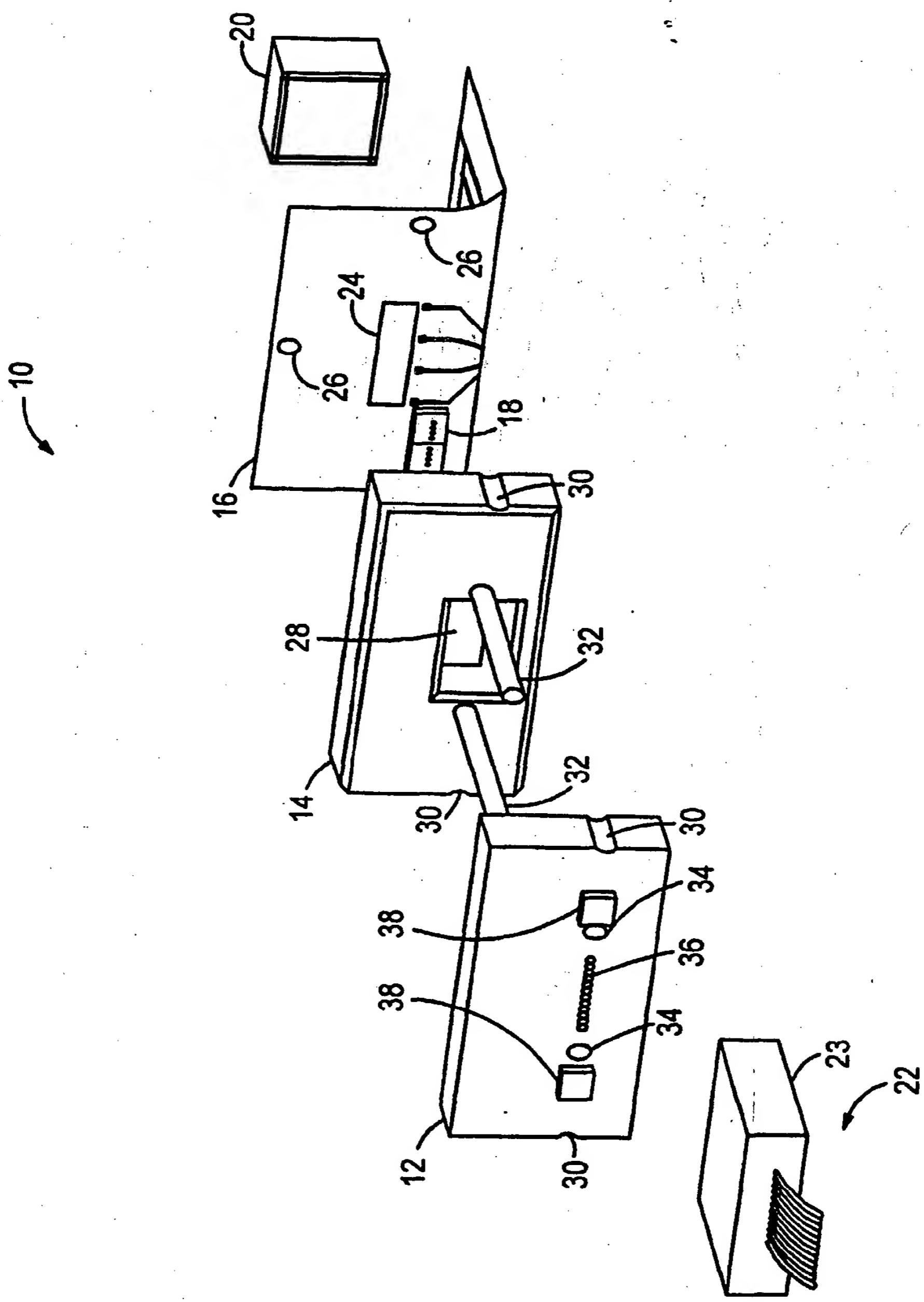


FIG. 1

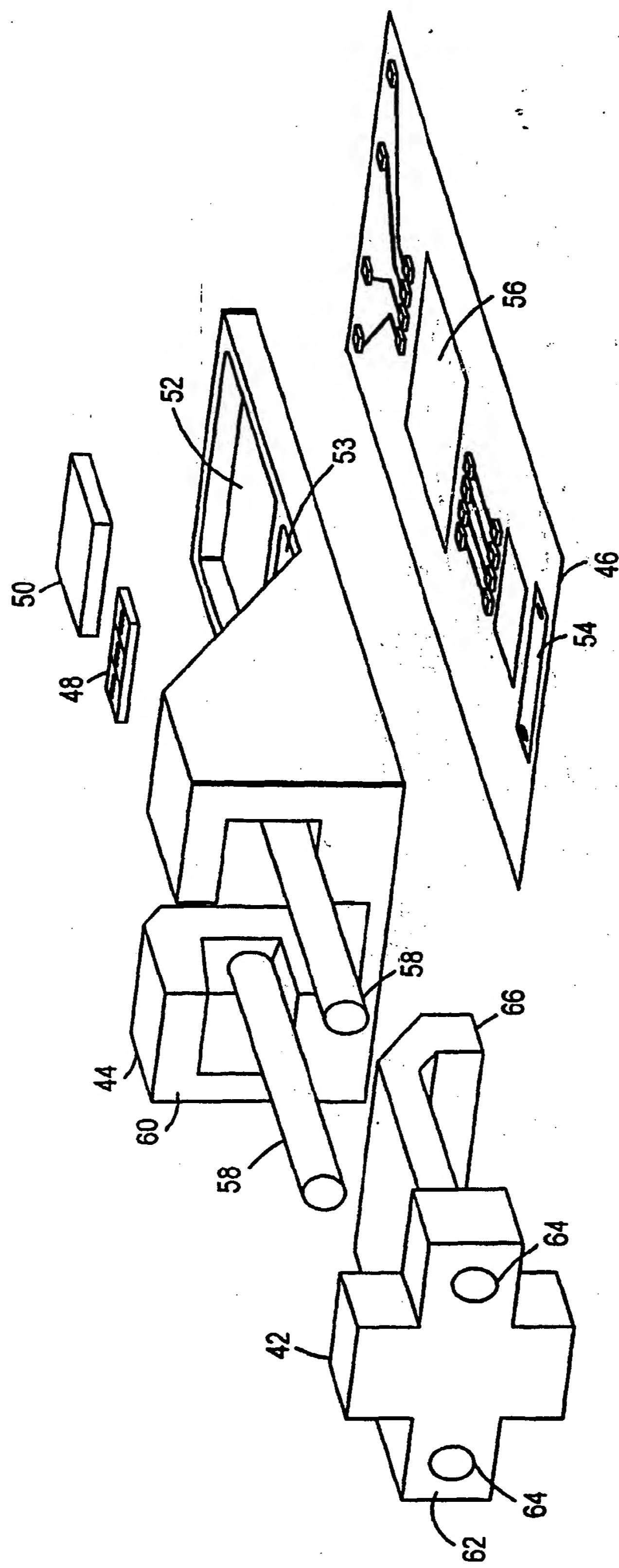


FIG. 2

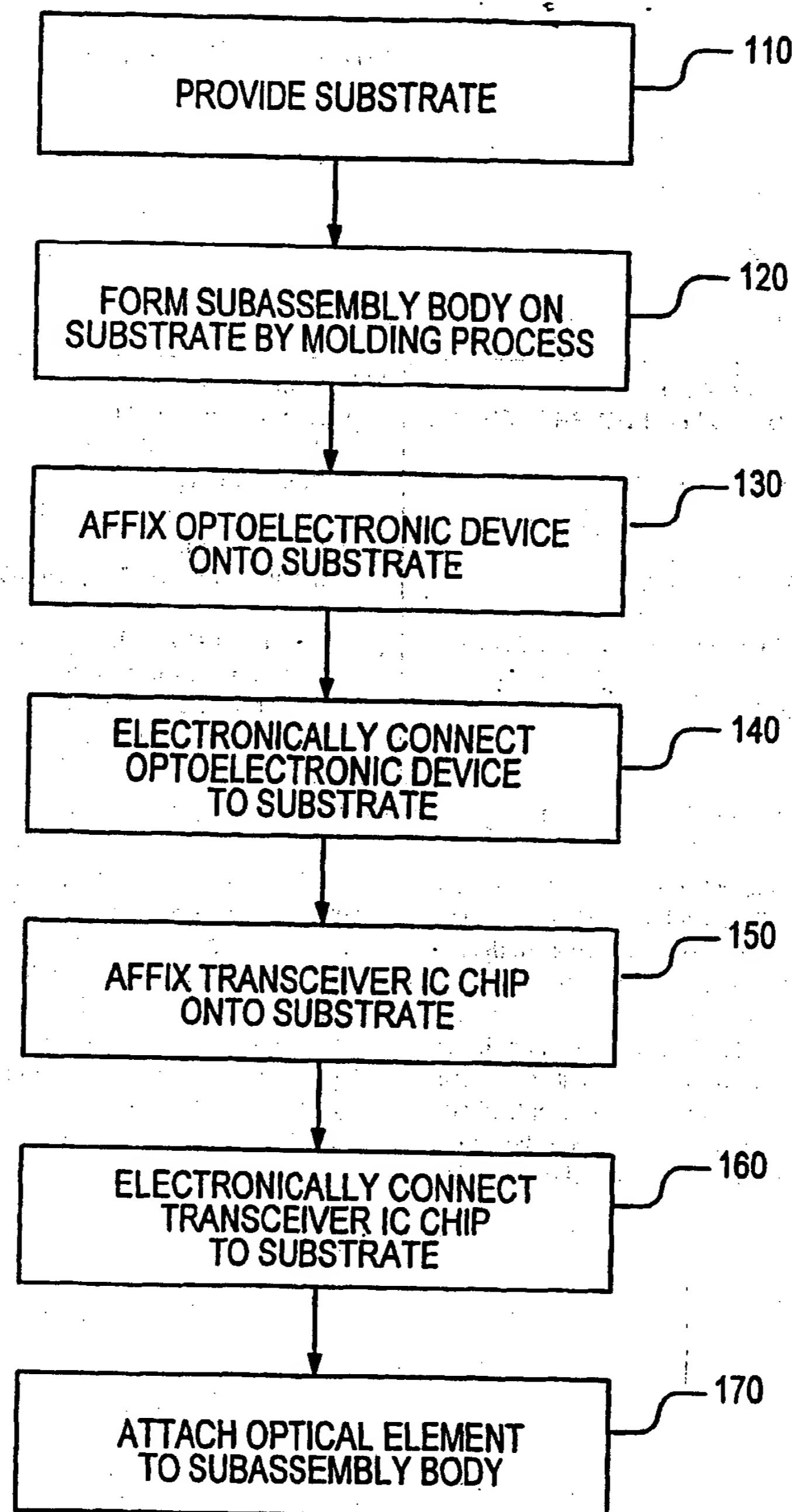


FIG. 3

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vice (18; 48), and a transceiver integrated circuit (IC) chip (20; 50). The optoelectronic device and the transceiver IC chip are affixed to the substrate. Preferably, the substrate is a flexible circuit having a number of electrical traces. The flexible circuit may be composed of a polymer material. The optoelectronic device is positioned on the substrate such that the optoelectronic device is located within an opening (28; 53) in the subassembly body. The opening may become an enclosed cavity when the optical element is attached to the subassembly body.

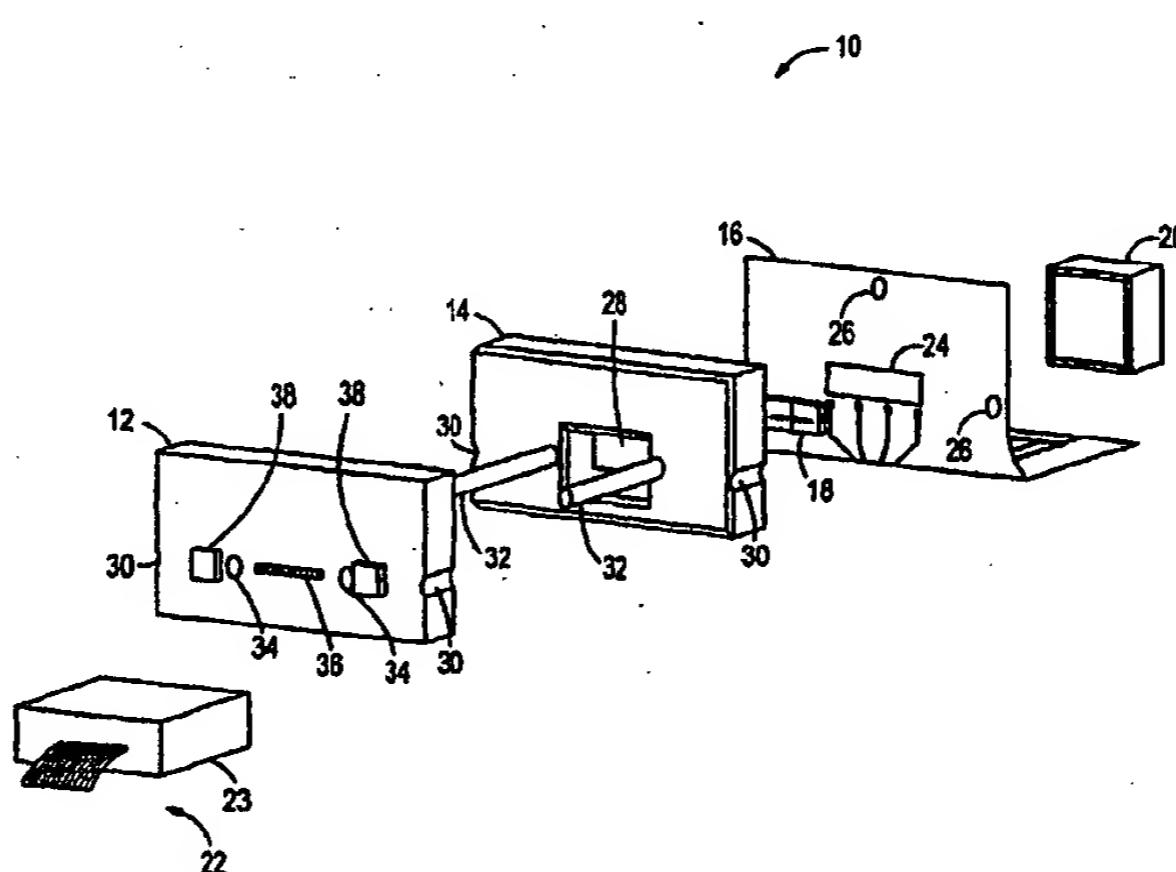


FIG. 1



## EUROPEAN SEARCH REPORT

Application Number  
EP 99 11 2850

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Place of search	Date of completion of the search	Examiner	
BERLIN	11 November 2002	von Moers, F	
CATEGORY OF CITED DOCUMENTS		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	
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